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THE LLOYD MIRROR EFFECT ON EXPLOSIVE SOURCES.(U)

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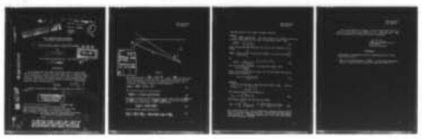

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THE LLOYD MIRROR EFFECT ON EXPLOSIVE SOURCES.

by

B. F. Cron

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INTRODUCTION

It is assumed that the reader is familiar with the Lloyd mirror effect (Reference 1). When this effect takes place a single source can be replaced by a dipole source. In this study, a transient signal source is considered. The energy spectrum of the received pulse is obtained. The equations for the filtered, integrated energy versus angle of arrival are also given.

ANALYSIS

12 4p.

Consider an impulsive source $\delta(t)$ and the geometry as given in Figure 1.

9 Technical memo.

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NUSL Principal Investigator: R.W. Hasse/R.L. Martin
Title of Project: Long Range Acoustic Transmission Experiments
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14 NUSL-TM-2211-186-70

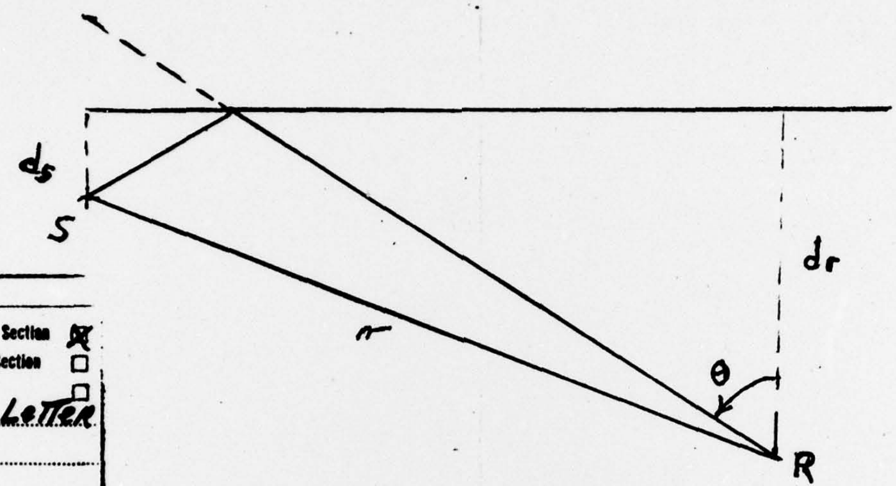

Figure 1

The received pulse is $\delta(t) - \delta(t-\tau)$, where $\delta(t)$ is due to the direct arrival and $-\delta(t-\tau)$ is due to the surface reflected arrival. τ is the difference in travel time between the two paths. By definition, the impulse response of this system is

$$h(t) = \delta(t) - \delta(t-\tau) \tag{1}$$

The transfer function of the system is

$$H(f) = 1 - \exp(-j2\pi f\tau) \tag{2}$$

Let us now consider an arbitrary pulse at the source given by $x(t)$ and let $X(f)$ be its spectrum. Let $y(t)$ and $Y(f)$ be the received waveform and spectrum, respectively. For a linear system,

$$Y(f) = H(f)\,X(f) \tag{3}$$

and the received energy spectrum is

$$E(f) = Y(f)\,Y^*(f) = H(f)\,H^*(f)\,X(f)\,X^*(f) \tag{4}$$

where $*$ represents the complex conjugate operator.

EXAMPLE

Let $x(t) = \exp(-at)$. The time history of an explosive source is sometimes represented by this type of exponential pulse. Then

$$X(f) = \frac{1}{a + j2\pi f} \tag{5}$$

Then substituting from equations (5) and (2) into equation (4), we obtain

$$E(f) = \frac{1}{a^2 + (2\pi f)^2}\left[(1 - \exp(-j2\pi f\tau))(1 - \exp(j2\pi f\tau))\right]$$

or

$$E(f) = \frac{4}{a^2 + (2\pi f)^2} \sin^2(\pi f \tau) \tag{6}$$

From the geometry in Figure 1, if $r \gg d_s$ and $r \gg d_R$, then

$$\tau \cong \frac{2 d_s d_R}{rc}$$

where c is the velocity of sound. For the far field, this may be approximated further by

$$\tau \cong \frac{2 d_s \cos\theta}{c} \tag{7}$$

RECEIVER

Let the receiver have a flat pass band from f_1 to f_2. That is,

$$H_R(f) = K, \quad f_1 \le f \le f_2$$
$$\quad -f_2 \le f \le -f_1$$

The energy output of this receiver is

$$E_0 = K^2\, 2\int_{f_1}^{f_2} E(f)\, df \tag{8}$$

Substituting equation (6) into (8), we obtain

$$E_0 = K^2\, 2\int_{f_1}^{f_2} \frac{4}{a^2 + (2\pi f)^2} \sin^2\left(\frac{\pi f\, 2 d_s \cos\theta}{c}\right) df \tag{9}$$

For a given f_1 and f_2, we can numerically integrate equation (9) to obtain the energy output for given θ. We can then plot the energy output versus θ. Numerical integrations of this type were made in the PARKA (Reference 2) study.

For a sharp pulse, a is large. If the frequencies f_1 and f_2 in equation (9) are small, such that $a >> 2\pi f$, then the $2\pi f$ term in the denominator of equation (9) may be eliminated.

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1. "Principles of Underwater Sound for Engineers," by R.J. Urick, McGraw Hill Book Co.

2. Hasse, R.W. and Martin R.L., "PARKA I - Acoustic Processing and Results," NUSL Tech Memo 2210-015-69, July 28, 1969. (C)